PHYSICS ADVANCES AND CHALLENGES

New scientific models and theories sometimes build on old ones, sometimes evolve in an attempt to explain experimental evidence or to describe the world in ordered and symmetrical terms, and sometimes first develop to answer questions for which there seem to be no answers. This course explores scientific models that fit into each of these categories. The process of understanding our world through science continues with each new discovery, new interpretation, and new question.

Eureka!

Sir Isaac Newton (1642–1727) formulated his ideas about gravity when an apple fell on his head while he sat quietly under a tree, or so the story goes. Newton went on to publish his ideas of force, motion, and universal gravitation in his book *Principia Mathematica* in 1687. In 1704, he published *Opticks*, sharing his understanding of the behaviour of light.

Newton's work was built on the ideas of scientists who came before him and has provided a framework on which a wealth of knowledge has been built over the past 300 years. Theories and models created from Newton's time until the end of the nineteenth century fall into the category known as "classical physics." At the beginning of the twentieth century, physicists made some startling discoveries that gave birth to entirely new scientific models. These new models fit collectively into what is called "modern physics," including special relativity, quantum mechanics, and the standard model of elementary particles. These new models are introduced in this text.

A Virtual Explosion of Scientific Advances

Imagine the sense of satisfaction that must have permeated the scientific community at the end of the nineteenth century. The industrial revolution, brought on by the advent of the steam engine in the mid-1700s, was maturing, thanks to the application of force and motion concepts. Jean Foucault (1819–1868) used a giant pendulum in 1851 to demonstrate that Earth did in fact rotate on its axis. Dmitri Mendeleev (1834–1907) had organized all of the known elements into what seemed to be a flawlessly logical periodic table. The great debate about whether light was best described as a particle or a wave seemed to be solved with the theory of electromagnetism in 1864. Finally, as the century drew to a close, the previously predicted and long-sought electron was discovered. Certainly a proud time for science — until it was turned upside down.

Einstein Questions Accepted Theories

Originally a patent clerk, a physicist of mounting fame named Albert Einstein published a scientific paper in 1905, presenting ideas that challenged the accepted scientific understanding of our universe. Einstein proposed two theories: the special theory of relativity that deals with motion at speeds close to that of light, and at a later date, the general theory of relativity that describes our universe in unified terms of space and time.

Einstein's experiments were not empirical; they were thought experiments. He did not sit in a lab running trials, but rather, used abstract

reasoning: If this, then that. One of Einstein's thought experiments led him to believe that time slowed down for objects travelling close to the speed of light — experimental observations to support most of Einstein's theories came later. You will have the opportunity to study Einstein's work and conduct thought experiments in Unit 5, Matter-Energy Interface.

A New Sense of Wonder

If Einstein's ideas had not replaced the scientific community's sense of satisfaction with a new sense of wonder, those of Max Planck (1858–1947) surely must have. The 1897 belief that atomic understanding would follow by applying current models to the structure of the atom turned out to be wrong. In 1900, Planck showed that energy radiated from matter was quantized: Rather than smoothly increasing or decreasing, like sliding up or down a hill, the energy stepped up and down in chunks, like an oddly built staircase.

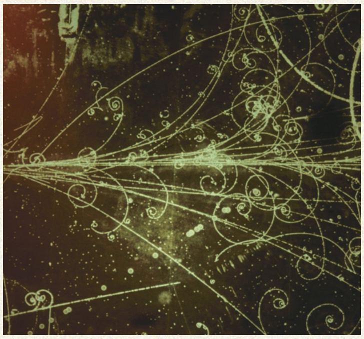
Niels Bohr (1885–1962) based his model of the atom on the concept of quantization of energy and momentum. In 1925, Erwin Schrödinger (1887–1961) synthesized the new concepts of quantization of energy in mathematical form. This field of physics, based on Schrödinger's wave equation, is called "quantum mechanics." Quantum mechanics provided (and continues to provide) unprecedented predictive powers.

Taking the Atom Apart

Initially, physicists assumed that there were only three fundamental constituents of matter: the proton, neutron, and electron. This assumption was shattered even before the neutron was finally found in 1932. More exotic particles were found, however, such as the muon, nutrino, and pion. So many new particles were found with each passing year that the term "elementary particle zoo" was used to describe them.

Finally, in the mid-1960s, a new idea surfaced, suggesting that all neutrons, protons, and related particles (hadrons) are composed of different combinations of quarks. Originally only three quarks were proposed, but soon, symmetry predicted the existence of six. Evidence for the existence of the sixth and final quark was discovered in 1995. Modern particle accelerators, capable of ever-increasing energy levels, continue to provide evidence of new particles composed of various combinations of these six quarks.

As you progress through this physics course, you will have the opportunity to develop a greater understanding of how the universe behaves, from planetary motion to the existence of energy fields and electromagnetic radiation, to the speed of light effects, to subatomic interactions of matter and energy. The progression of scientific understanding evolves with new discoveries and new ideas. You will have the opportunity to witness this continual process as you expand your own understanding.



Particles created inside large accelerators trace different tracks, depending on their mass and charge.

MOMENTOUS EVENTS IN THE HISTORY OF PHYSICS

- **1678** Wave model of light is proposed by Christiaan Huygens.
- **1687** Sir Isaac Newton publishes his *Principia Mathematica* on force and motion.
- **1740** Industrial Revolution begins, transforming society.
- **1747** Naming convention for charges (positive and negative) is proposed by Benjamin Franklin.
- **1785** Charles Coulomb discovers the inverse square relationship between force and charge.
- **1851** Jean Foucault's pendulum experiment verifies the rotation of Earth.
- **1869** Periodic table organizing all known elements is created by Dmitri Mendeleev.
- **1873** James Clerk Maxwell publishes his electromagnetism theory.
- **1895** X rays are discovered by Wilhelm Röntgen.
- **1896** Radioactivity is discovered by Henri Becquerel.
- **1897** The electron is discovered by J.J. Thomson.
- **1900** Blackbody radiation paper introducing early concepts of quantization of energy is published by Max Planck.
- **1905** Special theory of relativity is published by Albert Einstein.
- **1913** Model of hydrogen atom is presented by Niels Bohr.
- **1924** Wave nature of matter theory is published by Louis de Broglie.
- **1926** Wave equation is formulated by Erwin Schrödinger.
- **1965** Quark theory is proposed by Murray Gell-Mann and George Zweig.
- **1969** Neil Armstrong walks on the Moon.
- **1980** First scanning tunneling microscope able to image atomic scale structure
  First successful demonstration of fibre optic cable
- **1986** First high-temperature superconductor is discovered.
- **1989** Observation of Cygnus X-1, the first source of X rays found in the constellation Cygnus, provides strong evidence suggesting that its centre is a black hole.
- **1995** Sixth quark is discovered by Fermilab's Tevatron particle accelerator.